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AUTHOR Turner, Jeannine
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ABSTRACT

The Science Academy of Austin (Texas) was given a 4-year National Science Foundation (NSF) grant beginning in 1990-91. This evaluation report covers the third year of implementation. The grant provides a vehicle for linking the public and private sectors in Austin with the school system, providing in-depth partnerships for creating a thinking curriculum with two major goals: improving teaching skills with technology tools and increasing student learning and performance through holistic, interdisciplinary approaches. In the evaluated year, NSF funds provided staff development, student involvement in outreach activities in elementary schools, development of a groundwater curriculum for high school students, development of new private and public sector partnerships, followup on previous development, and additional staff. Evaluation suggested positive attitudes on the parts of teachers and students and useful curriculum changes. Recommendations are offered for program continuation. Ten figures illustrate the evaluation findings. (Contains 7 references.) (SLD)

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Constructing Tomorrow's Science Classrooms Today

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Final Report on The National Science Foundation Grant to The Science Academy of Austin, 1992-93

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SPECIAL APPRECIATION

Sue Sinkin-Morris was the director of the Science Academy of Austin from September 1987 through June 1993. For medical reasons, she retired at the end of the spring 1993 semester. The author would like to acknowledge the inspiration and leadership that Sue Sinkin-Morris provided in the development of the original grant request and in the first two and one-half years of the development and implementation of grant-funded programs. She was concerned with students' science and mathematics preparation in a technologically advancing world. Her vision for innovative curriculum development and teaching strategies with real-world applications continues.

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Constructing Tomorrow's Science Classrooms Today: The National Science Foundation Grant to The Science Academy of Austin, 1992-93

Executive Summary

Austin Independent School District
Office of Research and Evaluation

Author: Jeannine Turner

Program Description

The Science Academy of Austin was given a four-year National Science Foundation (NSF) grant beginning in 1990-91. This evaluation report covers the third year (of four) of the grant's implementation, from September 1992 to December 1993.

The NSF grant provides a vehicle for linking the public and private sectors in Austin with the school system, providing in-depth partnerships for creating a "thinking curriculum." This new curriculum has two major goals:

1. To improve teaching skills (grades K-12) with technology tools that are available but underutilized; and
2. To increase student learning and performance in science using holistic, interdisciplinary approaches with opportunities to apply concepts in real-world settings.

To address these goals, the NSF grant activities are divided into four components: *curriculum development, staff development, student participation,* and *private sector involvement.* From the beginning of the fall 1992 semester through the fall 1993 semester NSF funds provided:

- Staff development in technology and environmental issues;
- Student involvement in outreach activities to elementary schools;
- Development of *Watershed Studies*, a groundwater curriculum for high school students;
- Development of new private and public sector partnerships, as well as the expansion and/or maintenance of existing private and public sector linkages;
- Follow-up on previously funded curricular development and implementation;
- One half-time secretary;
- One half-time project facilitator; and
- One half-time evaluation associate to conduct program evaluation.

Major Findings

1. All curriculum development projects that NSF has funded have been in line with the grant's goal of developing integrative science courses that use holistic, interdisciplinary approaches. During 1993, a new curriculum that focuses on the impact humans have on water quality began development. The curriculum will be ready for piloting in local high schools in September 1994 (page 6).
2. Staff development was to focus on technology that is available but underutilized and innovative technology and programs. Participants in technology training indicated their training was relevant to their teaching and would be helpful and beneficial in organizing and running their classrooms (page 9).
3. Nearly all high school students who participated in elementary outreach activities believed their participation was important to the elementary students by making science learning fun and by providing them with role models for future academic success in science (page 14).
4. Forming partnerships with local corporations, government, and institutes of higher education produced resources and quality assurance. Participants from public organizations and private companies were involved in all aspects of grant implementation (page 18).
5. Surveys of the *Planet Earth* and *Science and Technology* students revealed that most students felt challenged, intellectually stimulated, and believed the information obtained in the courses was important. Surveys of the *Science and Technology* teachers revealed that the teachers felt that teacher collaboration was extremely important for planning and standardization of instruction and evaluation. Teachers also believe that the curriculum design promoted the application of learning to real-world problem-solving (page 23).
6. Observations of the *Science and Technology* classes suggested that the curriculum design promoted intrinsic motivation to learn. This finding was supported by teacher and student interviews (page 30).

Budget Implications

Mandate: External funding agency

Funding Amount: $349,250 (total for four years); 77,494 (for third year)

Funding Source: External; National Science Foundation

Implications: The grant provides funding to enhance student learning/involvement and addresses the District's first, second, and fifth strategic objectives:

- Every student will function at his/her optimal level of achievement and will progress successfully through the system;
- All students will function successfully at or above international standards; and
- The quality of course content and the effectiveness of instruction will be upgraded.

Funded activities also meet the District's strategies of:

- Motivating learning and defining student achievement;
- Incorporating the best technology into all aspects of the District's programs and operations;
- Providing optimal facilities and learning environments for all students; and
- Acquiring public and private funds for developing effective partnerships, including higher education, businesses, and the community.

Recommendations

Based on current evaluation findings, it is recommended that the Science Academy of Austin continue to use NSF funds, as outlined in the original grant plan to:

- Train teachers;
- Unite elementary students with senior high school students for teaching and mentoring;
- Develop innovative curriculum; and
- Develop and/or maintain linkages with private business and public services.

PROGRAM EFFECTIVENESS SUMMARY

1993 NATIONAL SCIENCE FOUNDATION (NSF) GRANT TO THE SCIENCE ACADEMY OF AUSTIN

PROGRAM COMPONENT	ALLOCATION (COST)	NUMBER OF TEACHERS PARTICIPATING	COST PER TEACHER	EVIDENCE	RATING
1993 NSF Curriculum Development Funding Source: External Grades: 9-12 Level of Service: Varies	$2,175	5	$435	Rating based on meeting grant objectives for curriculum development	+
1993 NSF Staff Development Funding Source: External Grades: K-12 Level of Service: Varies	$11,520	69	$167	Rating based on participant surveys and on meeting grant objectives for staff development	+
1993 NSF Linkages Funding Source: External Grades: 1-12 Level of Service: Year	$175,961*	N/A	N/A	Rating based on meeting grant objectives for public and private linkages	+
PROGRAM COMPONENT	**ALLOCATION (COST)**	**NUMBER OF STUDENTS PARTICIPATING**	**COST PER STUDENT**	**EVIDENCE**	**RATING**
1993 NSF Student Outreach Funding Source: External Grades: 1-12 Level of Service: Varies	$413	160	$3	Rating based on participant survey and on meeting grant objectives for student outreach	+

*Donations of cash and supplies or equipment; not part of grant allocation

Rating is expressed as contributing to any of the 5 AISD strategic objectives.

+	*Positive*, needs to be kept and expanded
0	*Not significant*, needs to be improved and modified
-	*Negative*, needs major modification or replacement
Blank	*Unknown*, may have positive or negative impact on other indicators; however, impact on the five AISD strategic objectives is unknown.

Cost is the expense over the regular District per student expenditure of about $4,000.

0	*No cost or minimal cost*
$	*Indirect costs* and overhead, but no separate budget
$$	*Some direct costs*, but under $500 per student
$$$	*Major direct costs* for teachers, staff, and/or equipment in the range of $500 per student

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CONCLUSION

The Science Academy of Austin met the objectives stated for the third year (beginning January 1993) of the National Science Foundation (NSF) grant. Overall, it appears that funds were used effectively to develop an innovative environmental curriculum for high school students, train teachers, unite elementary students with high school students for teaching and mentoring, and develop and/or maintain linkages with private business and public services.

During the third year of the grant, development of the high school curriculum *Watershed Studies* began. The curriculum was based on the grant's goal of developing integrative science courses that increase student learning and performance using holistic, interdisciplinary approaches with opportunities to apply concepts in real-world settings. *Watershed Studies* will be ready for piloting in local high schools in September 1994. In addition to the development of *Watershed Studies*, a consultant was hired to update the Science Academy's Biology I curriculum to integrate technological advancements.

As dictated by the grant, staff development focused on giving teachers innovative means to help students become technologically, scientifically, and environmentally literate, as well as to train elementary and secondary teachers in the use of available technology. Participants in training sessions indicated that they believed the training was relevant to their teaching and would be beneficial to students.

Science Academy and other LBJ students participated in elementary outreach activities that provided elementary students with hands-on science experience. Nearly all high school students indicated that they believed their participation was important to the elementary students, and because of their participation, some of the high school students stated that they are now more interested in teaching mathematics and science. In addition, high school participants in outreach activities indicated that they are now more interested in environmental issues.

To meet the grant's goals of improving teacher skills and developing interdisciplinary curricula that contain real-world applications, the Science Academy of Austin sought to develop and/or enhance linkages among elementary and secondary teachers, students, and university science faculty, as well as to develop and/or enhance linkages with public and private sector leaders in science and technology. Developing new, and maintaining established, academic linkages enhanced student learning for both elementary and secondary students. Linkages with public and private sectors enabled the Science Academy to acquire equipment, grants, training, technical advice, and assistance. In the 1992-93 school year, a total of $175,961 was donated to the Science Academy from businesses and individuals in the form of equipment/supplies ($16,678) and cash ($159,283).

Follow-up evaluation of previously NSF-funded curriculum development projects by students currently taking the courses revealed that most students in the NSF-funded courses felt challenged, intellectually stimulated, and believed the information they obtained in the courses was important. Teachers of one NSF-funded curriculum indicated that they believe the curriculum design promoted the application of learning to real-world problems and problem-solving. Furthermore, observations of classes using one previously funded curriculum supported the idea that the curriculum design promoted students' intrinsic motivation. This finding was further supported by teacher and student interviews.

EVALUATION OVERVIEW

Data for the 1992-93 evaluation of the National Science Foundation's grant to the Science Academy of Austin were obtained from the following sources.

- The NSF grant application provided information on goals, objectives, and time line for project implementation.
- The summary edition of *Project 2061: Science for All Americans* provided information on the recommendations of the American Association for the Advancement of Science (AAAS) for science curriculum development.
- Science Academy course information provided detailed descriptions of *Planet Earth* and *Science and Technology* course outlines and objectives.
- Interviews with the grant's project director, project facilitator, and project secretary provided detailed information on the implementation of and participants in curriculum development activities, staff development activities, student involvement activities, and private sector linkages.
- Questionnaires provided:
  - Teacher opinions of Technology Institute and/or River Watch Institute training,
  - *Science and Technology* teacher perceptions of the course and their experience in collaborating to plan standard instruction and student evaluations,
  - Student perceptions of the *Science and Technology* and *Planet Earth* courses, and
  - Student perceptions of their involvement in elementary outreach activities.
- Classroom observations provided information on student motivation in a course developed with NSF funds (*Science and Technology*).
- Interviews with *Science and Technology* teachers and students provided information on teachers' and students' perceptions of the students' motivation to learn in the *Science and Technology* classrooms. The interviews augmented classroom observations.

INTRODUCTION

In the spring of 1989 an innovative partnership, entitled Project A+, began between the IBM Corporation and AISD to "create a world class school system" by using computer technology as a catalyst for change. Within the framework of this innovative partnership, a four-year National Science Foundation (NSF) grant was given to the Science Academy of Austin (a magnet school located within LBJ High School) beginning in 1990-91 under the name "The Austin Science and Mathematics Consortium: A Private Sector Partnership for Tomorrow's World." In addition to the IBM Corporation, original consortium members included the Austin campus of The University of Texas' Science Education Center, the Lower Colorado River Association, Discovery Hall Science Museum, and the 25 corporations which supported the Science Academy of Austin and its programs. The Consortium sought to use the NSF grant to address three educational needs:

- Students' ability to be technologically, scientifically, and mathematically literate in work and society,
- Students' ability to identify environmental issues and generate solutions, and
- The use of available technology by science and mathematics teachers.

Addressing these needs, and recognizing the necessity for restructuring mathematics and science curricula in grades K-12, the grant provides a vehicle for linking the public and private sectors in Austin with the school system, providing in-depth partnerships for creating a "thinking curriculum." This new curriculum has two major goals:

1. To improve teaching skills (grades K-12) with technology tools that are available but under-utilized, and
2. To increase student learning and performance in science using holistic, interdisciplinary approaches with opportunities to apply concepts in real-world settings.

PROGRAM DESCRIPTION

To address the identified needs and goals, NSF grant activities are divided into four components:

- Curriculum development,
- Staff development,
- Student participation, and
- Enhancing public and private sector involvement.

The NSF grant to the Science Academy of Austin is atypical in that it does not conform to the academic year cycle (July to June), but begins in January each year. Each year of the grant has a specific focus on the curriculum development component. The staff development component contains annual summer training in technology (The Technology Institute), water quality testing and environmental action planning (The River Watch Institute), and training for specific curriculum development projects. Student participation and public/private sector involvements are ongoing, often cumulative, projects.

Breakdown of Grant Activities by Year

Year 1: 1991

The first year of the grant (beginning in January 1991) focused on initial grant implementation and development of two curricula:

- *Planet Earth*, a curriculum for tenth-grade students integrating geology, physics, earth science, chemistry, and biology, and
- *Nonpoint Source Pollution* (NSP), a curriculum for seventh- and eighth-grade students, which deals with nonpoint source pollution (pollution not attributable to a specific source such as a factory).

Also during the first year of the grant, teacher training in The Technology Institute, The River Watch Institute, and training for teachers of grades K-2 for the *Science for Life and Living* curriculum were initiated. Science Academy students conducted outreach activities with the students of teachers who attended the 1990 summer training, and private sector involvement was quite extensive (see ORE Pub. No. 90.37).

Year 2: 1992

During the second year of the grant (beginning in January 1992), the three curricula developed the previous year were piloted in selected AISD schools. A new curriculum for the ninth grade called *Science and Technology* was developed. The *Science and Technology* curriculum integrates technology, telecommunications, engineering, and physical science. Summer staff development activities included The Technology Institute, The River Watch Institute, and training for teachers of grades 3-5 for the *Science for Life and Living* curriculum. As in the previous year, students conducted outreach activities with the students of teachers who attended the summer training, and private sector involvement was extensive (see ORE Pub. No. 91.25).

Year 3: 1993

This evaluation report is on the third year of the NSF grant (beginning January 1993). Program objectives for the third year included:

- Development of *Watershed Studies*, a groundwater curriculum for high school students,
- Continued staff development in technology and environmental issues,
- Continued student involvement in outreach activities,
- Development of new private and public sector partnerships, as well as the expansion and/or maintenance of existing private and public sector linkages, and
- Follow-up on previously funded curriculum development and implementation.

Because the previous NSF final report was written in August 1992, this report will also describe some activities which occurred in the fall of 1992, including student outreach activities and classroom observations conducted on the *Science and Technology* course that semester.

CURRICULUM DEVELOPMENT

During 1993, the final NSF-funded curriculum development began. The high school curriculum, called *Watershed Studies*, focuses on the impact humans have on water quality. Statewide water concerns are included to give central Texas students a meaningful perspective on local and state water quality issues. The curriculum will be ready for piloting in local high schools in September 1994.

All Science Academy curriculum development projects that used NSF funds have been in line with the grant's goal of developing integrative science courses that increase student learning and performance using holistic, interdisciplinary approaches with opportunities to apply concepts in real-world settings. Additionally, they are also aligned with the science and environmental education reform recommendations developed by the American Association for the Advancement of Science in its Project 2061 program. Project 2061 recommends that reforms in curricula should:

- Be thematic in their interdisciplinary approaches,
- Motivate students to think, solve problems, and make practical applications of scientific knowledge, and
- Present plans for actions which challenge students to change behavior(s).

The *Watershed Studies* Curriculum

During the summer of 1993, the final NSF-funded curriculum development began. The nascent curriculum is called *Watershed Studies* and is being developed for high school use. The main focus of the curriculum is the impact humans have on water quality. Statewide water concerns are included to give central Texas students a meaningful perspective on local and state water quality issues (e.g., subsidence due to ground water pumping and salt water inflow from abandoned oil wells). Another aspect of the curriculum seeks to create an awareness of how personal actions can affect water quality. The curriculum is designed to present various ways for students to effect change. Another aspect of the curriculum focuses on career development and future water quality issues.

The curriculum-writing was done by a team of local science teachers and water quality specialists. The 11-member curriculum-writing team consisted of:

- Seven (7) AISD high school science teachers from four (4) schools,
- One (1) graduate student (a former AISD middle school teacher),
- One (1) representative from the Brazos River Authority in Waco, Texas
- One (1) representative from the Lower Colorado River Authority in Austin, Texas, and
- The NSF project facilitator.

See "Linkages" section for more detail.

The curriculum-writing team met twice during the summer and once during the 1993 fall semester. The objectives for the meetings were to formulate and refine the scope and sequence of the curriculum. Between meetings, individual team members worked on literature searches, activity ideas, personal contacts, and revisions to the scope and sequence outlines.

At the end of 1993, the *Watershed Studies* curriculum had ten (10) sections. One section covers historical elements, one section covers physical/biological factors, six sections address current issues, and two sections address future water quality issues. The four units and their sections are listed in Figure 1.

FIGURE 1
***WATERSHED STUDIES* CURRICULUM**
DECEMBER 1993

History (one section) • The historical importance of water to society
Physical/Biological Sciences (one section) • The physical and biological factors that determine a Texas watershed and the associated groundwater resources
Current Issues (six sections) • Current available water resources in the State of Texas and the rate of usage • Contemporary regional water quality issues and case studies important to the health of the main Texas watersheds and aquifers • Nonpoint sources of water pollution in an urban environment and in the rural areas of Texas • Effective watershed management strategies in preventing groundwater and surface water pollution • Texas water rights and federal and state water quality laws • Role of the individual citizen in water pollution prevention and abatement efforts
The Future (two sections) • Future concerns with wildlife habitat, irrigation, drinking water, and recreational uses that require conflict resolutions • Importance of new technologies, future population size, and a global economy on Texas water resources

Future Development and Implementation

As of January 1994, the *Watershed Studies* curriculum was not yet ready for implementation. Several procedures are on the curriculum development agenda for the 1994 grant year. The final scope and sequence revision meeting was in January 1994. At that time, learning objectives were also determined. Once the scope and sequence was completed, it was sent to LCRA to review. During the spring 1994 semester, a technical advisory team, consisting of professionals outside AISD and LCRA, met three times to review and refine the curriculum's scope and sequence and learning objectives. During summer 1994, lesson plans will be written by ten (10) science teachers. Piloting of the curriculum will begin in fall 1994 in selected AISD high schools. LCRA has applied to the United States Environmental Protection Agency for additional funding in order to complete the teaching guide and to disseminate the final product to high school teachers in central Texas counties. Final development and implementation procedures will be recounted in the 1994 NSF final report.

Curriculum Update

In addition to the curriculum development of *Watershed Studies*, a consultant was hired to update the Science Academy's Biology I curriculum to incorporate the use of Hypercard and Internet (advanced computer) technologies into the course. In accordance with grant intentions, NSF grant funds were used to update this curriculum to incorporate technological advancements.

STAFF DEVELOPMENT

In accordance with grant specifications, staff development focused on available technology, as well as on innovative technology and programs. Participants in technology training indicated that their training was relevant to their teaching and would be helpful and beneficial in organizing and running their classrooms.

During 1993, several types of staff development were funded with NSF grant money. The aim of NSF-funded staff development is to:

- Train teachers in computer technology in order to reduce their workload,
- Improve teacher instruction through the use of technology, and
- Give teachers innovative means to help students become technologically, scientifically, environmentally, and mathematically literate.

The Technology Institute

The purpose of technology training is to train, assist, and/or inform teachers of technology that is available but underutilized. Often, this training focuses on the use of available computer programs. Each year of NSF grant implementation, a Technology Institute has been held.

In the summer of 1993, two technology training programs were conducted. One of the training programs focused on computer programs that could assist elementary teachers; the other focused on computer training that could assist secondary teachers. All participants were sent a questionnaire designed by ORE which focused on teacher perceptions of the helpfulness and usefulness of the training they had received at the Technology Institute.

Elementary Training

A Technology Training Institute was held at Winn Elementary School the week of August 9-13, 1993. Of the 23 teachers who attended the institute, 21 (91%) were elementary teachers. The other participants were middle (1) and high (1) school teachers. The training was centered on computer programs which could ease a teacher's workload and help organize classroom data. Teachers received training on:

- Microsoft Works - word processing, database management, spreadsheet, and
- Express Publisher.

Teachers were given hands-on instruction to learn the computer programs. Group discussions explored ideas on how to use the programs to keep records, begin the school year, organize student information, and create forms, letterheads, parent letters, and banners. Individualized instruction was also given to teachers who had specific needs or problems.

At the close of the training, the presenters distributed a questionnaire containing open-ended questions to obtain participant feedback. Eighteen (18) of the 23 participants responded to the questionnaire (a 78% response rate). All (100%) respondents agreed that:

- The presenters were knowledgeable and the training objectives were clear;
- The training was relevant to their teaching and would be helpful and beneficial in organizing and running their classrooms; and
- They would recommend the training to other colleagues. One teacher specified that the training would be most beneficial to a person who "is in need of basic skills or interested in exploring the particular programs."

Seven (7) of the 23 participants responded to an ORE follow-up questionnaire (a 30% response rate) that was distributed after the beginning of the fall 1993 semester. Because the response rate is only 30%, these findings may or may not represent the opinions of the majority of participants. Responding participants strongly agreed/agreed that:

- The skills they learned in the technology training are important (100%);
- As a result of the technology training, their repertoire for using computer technology in the classroom was greatly increased; and
- The technology training was challenging (100%) and stimulating (86%).

In addition, most teachers responded that they have used the information from the technology training very often (71%) and that the materials/techniques required no modification, or some but not much modification, to be used in the classroom (71%).

Secondary Training

A Technology Training Institute was held at the regional Educational Service Center the week of August 9-13, 1993 for secondary teachers. Additionally, technology training was held at LBJ High School on July 30, 1993 and August 2-5, 1993. Of the 28 teachers who attended the training sessions, 7 (25%) were elementary teachers, 5 (18%) were middle school teachers, and 15 (54%) were high school teachers. The training was centered on using word processing and on TENET, a computer interface system.

Fifteen (15) of the 28 participants responded to the ORE questionnaire (a 54% response rate). Regarding their amount of computer experience, 6 (40%) indicated they had 6-10 years of experience, 4 (27%) indicated they had 5-6 years of experience, and 1 (7%) indicated having 3-4 years of experience. Two (13%) respondents had no prior computer experience, and two (13%) of the respondents chose to not answer the item.

Responding participants strongly agreed/agreed that:

- The skills they learned in the technology training are important (93%);
- The technology training was challenging (73%) and stimulating (87%); and
- They would recommend this training to other teachers (87%).

In responding to an open-ended question concerning recommended changes to the training, two (13%) participants indicated that the broad range of computer experience (0-10 years experience) among participants created teaching problems. Both respondents agreed that computer training should be targeted to specific experience levels. Two participants who had indicated they had no prior computer experience, and one participant who chose to not indicate a level of experience, responded that the training was too advanced for those with little computer experience, and at times they felt "overwhelmed by all the information."

Three respondents (20%) indicated that, although they believed the training was important, they did not have computers in their classrooms. They thought that the lack of available computers limited the effect the technology training had on them.

A strong emphasis was placed on teachers making a successful transition from learning a technological skill to actually using that technology in the classroom. Teachers who participated in NSF-funded technology training were asked to develop plans illustrating how they would incorporate aspects of the training into their courses. They submitted their plans on the last day of the training session.

The River Watch Institute

One training session held during the 1993 grant year involved water quality issues. The training, held in July 1993, focused on river water inhabitants and is considered an "advanced" course. The teachers who attended this week-long session on biological monitoring had previously participated in river water monitoring.

Biological Monitoring

The biological monitoring training was developed by LCRA and the Colorado River Watch Network (CRWN). The week-long training held in August 1993 at Lake Buchanan focused on the study of river macroinvertebrates (water inhabitants with no backbones that are large enough to be seen with the naked eye) in the Colorado River and its tributaries. Macroinvertebrates are a better indication of an ecosystem's health because they demonstrate the impact of water contaminants rather than just the presence of contaminants. By obtaining habitat assessments in concert with chemical monitoring, a more complete appraisal of the presence and effect of water pollution (or the lack of it) can be made of the Colorado River and its tributaries.

In conjunction with the 1992 Federal Clean Water Act's objective to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," the biological monitoring training had six (6) primary goals:

1. Involve teacher/student/citizen volunteers as biomonitors,
2. Illustrate relationships between the chemical water quality parameters, habitat parameters, and biological parameters,
3. Educate and inform participants about stream ecology,
4. Encourage the interest in the biodiversity of small life forms,

5. Study/document natural or unnatural changes in the benthic (river-bottom) community, and

6. Document seasonal changes in macroinvertebrate populations.

Participants for the biomonitoring training were recruited from newsletters of the LCRA, CRWN, and the Texas Water Commission. At the close of the training, the 23 participants responded to a survey designed by CRWN. The survey consisted of five (5) Likert scale items and five (5) open-ended statements. Results of the survey indicated participants believed that:

- The information/activities they learned would be very (87%) or considerably (13%) beneficial,
- The workshop setting was very (83%) or considerably (17%) adequate,
- The workshop was just right (96%) in length, and
- The overall rating of the workshop was very (87%) or considerably (13%) good.

Responding to the statement "The subject or activity I most enjoyed was:" participants offered:

- Identification of bugs,
- Indicators for different types of environments, and
- Discussing the habitat assessment criteria at the site.

Addressing the question "What subjects or themes would you like to see covered in future workshops?" participants responded:

- A short presentation on insect life cycles and a summary of an ideal benthic community and its seasonal changes,
- More on both invertebrates and vertebrates and how they affect the water and ecosystems, and
- How our lifestyles affect the environment and how we could possibly change our lifestyles.

Additional Training

According to the Science Academy director, other staff development activities occurred during 1992-93. These activities were implemented but not evaluated. In addition to the annual technology training and river watch training, the following training occurred:

- A group of 30 Science Academy teachers, students, and administrators attended a special, introductory Hypercard training at the Region XIII Educational Service Center on October 20, 1993. The training was held specifically for the Science Academy. Students and teachers who attended the training shared their knowledge with other teachers and students at the Science Academy.

- Training in Clarisworks, Hypercard, Superprint, Basic Writer, and Advanced Bank Street was held at Becker Elementary School for interested elementary teachers.

- IBM offered the use of its Decision Support Center for Science Academy teachers. Sixteen (16) staff members learned how the use of technology can facilitate the process of strategic planning, and each developed a strategic plan for the Science Academy.

STUDENT OUTREACH

During 1992-93, Science Academy and other LBJ students participated in elementary outreach activities in which high school students provided elementary students with environmental instruction and hands-on science experience. Nearly all high school students believed their participation was important to the elementary students by making science learning fun and by providing them with role models. Because of their participation, some of the high school students are now more interested in teaching mathematics and science, and many are more interested in environmental issues.

To assist in linking elementary with secondary learners, Science Academy and other LBJ students enrolled in the Environmental Science class participated in elementary outreach activities during the fall 1992, spring 1993, and fall 1993 semesters. Because data were collected in January 1994 for the fall 1993 class, only the fall 1993 and spring 1994 classes are described in this report.

The participating high school students provided elementary students from Becker, Brooke, Cook, Campbell, Pease, Winn, and Williams elementary schools with environmental instruction and hands-on experimental lab experience. The high school students also provided mentoring in learning situations and role modeling for staying in school. Outreach activities for the third year of the NSF grant included:

- Tours of Pioneer Farms, the Nature Center, and water treatment plants,
- In-class instruction of hands-on science experiments and labs,
- Assistance with construction of solar cars for a solar car race, and
- Judging of elementary school science fairs.

Outreach Project

In addition to traditional textbook and lecture teaching formats, high students enrolled in the Environmental Science course at the Science Academy must also be involved in a semester-long, environmentally focused project. One option for the project is for students to manage an elementary outreach activity. Students who select this option work in a team consisting of three or four students. The team is responsible for all aspects of the outreach activity which include:

- Choosing/designing the activity,
- Contacting the prospective elementary school and teachers,
- Organizing and conducting lessons, and/or
- Coordinating and conducting on-site visits and tours, which includes bus transportation and school leave for students.

The activities are intended to have a positive effect on the elementary children by using high school students as mentors and role models and to expose elementary students to environmental/science concepts. After the completion of the activity, elementary students often send the high school students thank-you letters and pictures expressing how much they learned from the activity and their appreciation for the experience.

The outreach activities are also intended to have an effect on the high school students. The students carry the full responsibility for organization and implementation of the activity. This responsibility requires them to create and meet task deadlines and to do so in collaboration with team members. Additionally, high school students experience working with children in a leadership and teaching role.

Outreach Survey Results

At the end of the fall 1992 and spring 1993 semesters, high school students who participated in outreach activities were asked to complete an ORE-designed questionnaire during class time. Two of the items allowed respondents to "choose all that apply," and one item was rated on a five-point Likert scale ("very important" to "not at all important"). There were also six (6) open-ended questions to allow students to give unconstrained answers. The focus of the questionnaire was on the students' perception of their experiences and the effects of their participation (see Figure 2). All of the students who participated in elementary outreach projects, and were given questionnaires, completed and returned them (N = 21).

The student survey revealed the following information.

- Most students chose to participate in outreach programs because their teacher made it sound interesting (67%) and because they are interested in the environment (62%). "Other" reasons listed for their participation included:
  - Interest in working with and teaching children, and
  - Wanting to make a difference in society.

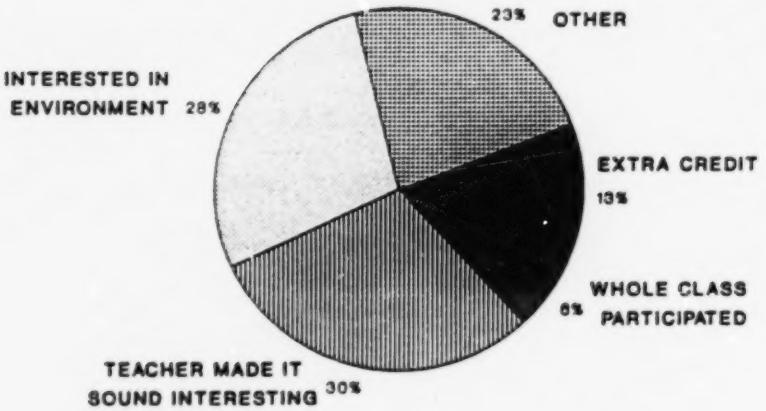
- Most students feel their participation in the outreach activities has made them more interested in environmental issues (62%), and a few students (14%) indicated they are now more interested in teaching mathematics and/or science. "Other" effects on the students included:
  - That there are many children "out there" who want to learn,
  - It's fun to teach children, and
  - It's important to work with children.

- Nearly all students believed their participation was very (62%) or somewhat (28%) important to the elementary students.

FIGURE 2
1993 STUDENT OUTREACH SURVEY RESULTS

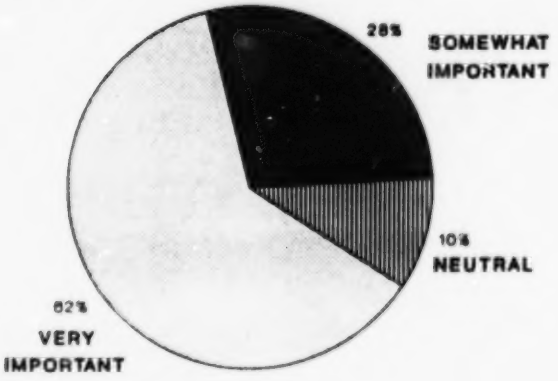
WHY ARE YOU PARTICIPATING IN THE OUTREACH PROGRAM?
(Choose all that apply)

N = 47 total responses by 21 respondents



HOW IMPORTANT DO YOU FEEL WAS YOUR PARTICIPATION IN THE OUTREACH PROGRAM?

N = 21



Responding to the question, "What did you find most rewarding about participating in the Outreach Program?" students offered the following comments:

- The reaction of the kids and knowing that we could put a program like this together.
- The joy the students had in learning about the environment.
- The thank-you cards, drawings and homemade booklets were the most rewarding. They showed me that the teachers and their kids appreciated our effort as a group.

In addition to comments about teaching the elementary students specific science concepts, students responding to the question, "How do you think you affected the students you worked with at the elementary school?" also offered:

- We helped them realize how fun learning about science can be.
- I feel that it encouraged them to continue on in school--seeing older peers involved in school [who are] willing to teach and show them around.
- I think I helped these kids be more aware of the world around them. I think they also got more interested in science subjects. I think we gave them a role model and someone to look up to--some of these children really need that.

In responding to questions about challenges and difficulties, most comments centered on the students' realization of the need for better planning and organization. Additionally, other responses to "What did you find most challenging about participating in the Outreach Program?" included:

- Making difficult topics easy for children to understand;
- Trying to maintain the complete interest of the class; and
- The questions the students asked--We were amazed what these kids knew!

Additional Outreach Activities

In addition to the outreach activities accomplished through the Environmental Science course, the following endeavors were also accomplished by Science Academy students with elementary students:

- In nearby Eanes and Round Rock school districts, students presented sessions at an elementary "Early Earth Day" celebration;
- Students presented a creek study and a science demonstration at the Science Fun Day that was sponsored by The University of Texas College of Natural Sciences and held at a local shopping mall; and
- Physics students participated in physics circuses at Lee Elementary School.

LINKAGES

Forming partnerships with local corporations, government, and institutes of higher education produced resources and quality assurance. Public and private organizations are involved in all aspects of grant implementation.

The National Science Foundation's (NSF) grant to the Science Academy of Austin focuses on issues of technology and curriculum by improving teacher technology skills and developing interdisciplinary curricula that contain real-world applications. To meet these goals, the Science Academy of Austin has sought to develop and/or enhance linkages among elementary and secondary teachers, students, university science faculty, as well as public and private sector leaders in science and technology. Linkages augment student learning for both elementary and secondary students through the use of student outreach activities (see "Student Outreach Activities"). By forming public and private sector linkages, the Science Academy has been able to acquire equipment, grants, training, technical advice, and assistance. For the history of Science Academy linkages, as well as linkages formed during the first year of the NSF grant, see Williams-Robertson's Forming Linkages and Private Sector Partnerships (ORE Publication No. 91.11).

The Science Academy Advisory Board

The Science Academy Advisory Board is comprised of representatives from local corporations, higher education institutions, and AISD. The Board provides assistance and consultation in program and staff development and facilitates donations. The current Science Academy Advisory Board is composed of the members listed in Figure 3.

FIGURE 3
1993 SCIENCE ACADEMY ADVISORY BOARD

Vaughn Aldridge **AT&T Long Distance Company**	Exalton Delco, Ph.D. (Retired) **Austin Community College**	Pete Palazzari **IBM Corporation**
H. David Balfour, Ph.D. **Radian Corporation**	Lester Formby **Motorola Corporation**	Syed Rizvi **Sematech Corporation**
Ruben Betancourt **Abbott Laboratories**	Rudy Garza **S. A. Garza, Engineers**	Shirley Sandoz **Lockheed Corporation**
Terry Bishop, Ph.D. **Austin Independent School District**	William Kennedy **Texaco Chemical Company**	Ron Shelly **Texas Instruments**
Mel Bland **Applied Materials**	J. J. Legowski, Ph.D. **The University of Texas**	Keith Thomas **Texas Instruments**
W. H. Breder, Ph.D. (Retired) **Texaco Chemical Company**	Milton Lee **City of Austin**	Toni Turk, Ph.D. **Austin Independent School District**
Gerald Briney (Retired) **IBM Corporation**	Paul Leeke **3M Corporation**	Charles Werlick, Ph.D. **University of Texas, Computer Center**
John Clemmons **Southwestern Bell Telephone Company**	Mary Long **Science Academy of Austin**	Sam Zigrossi **IBM Corporation**
	George More III **George More Investments**	

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Public and Private Sector Involvement

By forming partnerships with local corporations, government, and institutions of higher education, the Science Academy has been able to obtain financial and equipment resources and also to assure the quality of existing and developing programs. Participants from public organizations and private companies are extensively involved in all aspects of NSF grant implementation.

Yearly donations of equipment and/or cash are reported to AISD's Adopt-A-School office at the end of March for each school year. Donations of equipment and cash described in this report are for the 1992-93 school year. Donations for the 1993-94 school year will be described in the 1994 NSF final evaluation report.

In the 1992-93 school year, a total of $175,961 was donated to the Science Academy from businesses and individuals in the form of equipment/supplies ($16,678) and cash ($159,283). See Figures 4 and 5.

FIGURE 4
DONATIONS OF EQUIPMENT/SUPPLIES
TO THE SCIENCE ACADEMY, 1992-93

DONOR	DONATION	VALUE
Madeline Bailey	Computer software	$250
IBM Corporation	56 SX computers 20 printers 30 color monitors 70 keyboards A group of nonfunctioning computers from which 25 computers were built	$10,000
Lockheed	Computer software	$500
Mary Long	Magazines: *Nature* and *Scientific American*	$171
Sue Sinkin-Morris	Magazine: *Science*	$87
Southwest Texas State University	Lab glassware	$100
Texas Chemical Company	3-ring binder Systems interface module that goes with gas chromatograph Digital 380 computer & software	$3,000
Texas Instruments	Books Laser printer 10 TI-81 calculators 1 TI-81 overhead viewer	$2,570
TOTAL		$16,678

FIGURE 5
DONATIONS OF CASH
TO THE SCIENCE ACADEMY, 1992-93

DONOR	PURPOSE	AMOUNT
3M Austin Center	Science Academy senior recognition banquet	$1,000
Allan Adams	Salary supplement for teacher	$100
Mr. & Mrs. Bob Backlund	Science Academy senior recognition banquet	$100
Gerald Briney	For teacher to attend conference	$333
Dr. Jimmy Humphrey	Scholarship divided among four students	$1,200
IBM Corporation	Science Academy senior recognition banquet	$750
Lockheed	Science Academy senior recognition banquet	$500
George More Investments	Science Academy senior recognition banquet	$100
Radian Corporation	Science Academy senior recognition banquet Computer	$3,500
Sematech	Science Academy senior recognition banquet	$100
Southwestern Bell Telephone	Science Academy senior recognition banquet	$300
Texaco Chemical Corporation	Science Academy senior recognition banquet	$300
Texaco Foundation	Grant: provides for equipment, supplies, summer school for middle school students & teacher training	$150,000
Texas Instruments	Science Academy senior recognition banquet	$750
Dr. Charles Warlick	Science Academy senior recognition banquet	$250
TOTAL		$159,283

Technical advisory committees were formed for the development of the *Science and Technology* and *Watershed Studies* curricula. The advisory committees met several times to review objectives, provide content guidance, suggest real-world application activities, and assure the quality of the final products. Committee members are listed in Figures 6 and 7.

FIGURE 6
***SCIENCE AND TECHNOLOGY* CURRICULUM**
DEVELOPMENT COMMITTEE AND TECHNICAL ADVISORS

Science Academy of Austin Acting Director
Mary Long

Science Academy of Austin Teachers
Anthony Bertucci, Industrial Arts, Technology
Arthur Brenner, Physical Science, Physics, Computers
Leila Dumas, Physical Science, Physics
Jackson Pace, Physical Science, Physics, Biology
Ken Tothero, Physics, Instructional Technology
Meredith White, Chemistry, Physical Science

Office of the Governor, State of Texas
Joseph Wiseman, Energy Office

Motorola Corporation
Curt Wyman, Engineer

University of Texas Physics Department
Harry Swinney, Ph.D.
Jack Turner, Ph.D.

University of Texas Engineering Department
Kristin Wood, Ph.D., Mechanical Engineering

University of Texas Science Education
Frank Crawley, Ph.D., Physical Sciences, Physics, Chemistry

FIGURE 7
***WATERSHED STUDIES* CURRICULUM**
DEVELOPMENT COMMITTEE AND TECHNICAL ADVISORS

Science Academy of Austin, NSF Grant Facilitator
Wes Halverson, Ph.D.

Agencies
Tom Conry, Brazos River Authority
Donna Darling, Texas Water Development Board
Marshall Frech, Texas Environmental Center
Nancy Lockhoof, Ph.D., Texas Agricultural Extension Service
Robin Loving, Keep Austin Beautiful
Irene Pickhardt, Texas Education Agency
Melissa Sabatino, AISD Office of Research and Evaluation
John Waugh, Edwards Underground Water District
Bill West, Guadalupe-Brazos River Authority

Educators
Karen Farley, Southwest Educational Development Laboratory
Robert Furtado, Anderson High School
Bill Glover, Austin High School
Tim Fennell, LBJ High School/Science Academy
Maria Ruiz-Diaz, Johnston High School
Allen Johnson, LBJ High School/Science Academy
Pat Smith, LBJ High School/Science Academy

Lower Colorado River Authority
Karen Farabee, Manager, Corporate Communications
Mary Gilory, Coordinator, Water Quality
Troy Kimmel, Chief Meteorologist, Water Resources
Nora Mullarkey, Coordinator, Water Efficiency
John Williams, Coordinator of Education Programs

University
Mike Bishop, Graduate Student, Southwest Texas State University
Leon Long, Ph.D., University of Texas at Austin

FOLLOW-UP EVALUATIONS

Most students of the *Planet Earth* and *Science and Technology* courses indicated that they felt challenged, intellectually stimulated, and believed the information obtained in the courses was important. Teachers of the *Science and Technology* course believe that teacher collaboration was extremely important for planning and standardization and that the curriculum design promoted the application of learning to real-world problems and problem-solving.

Two curricula, *Planet Earth* and *Science and Technology* were chosen for follow-up study during the NSF grant's third year. Both courses were deliberately generated with the intention of developing integrative science courses that:

- Increase student learning and performance using holistic, interdisciplinary approaches,
- Are thematic in their interdisciplinary approaches,
- Motivate students to think, solve problems, and make practical applications of scientific knowledge,
- Contain opportunities to apply concepts in real-world settings, and
- Enhance students' ability to identify environmental issues and generate solutions.

Additionally, these courses were chosen for follow-up study because the development of both curricula commanded extensive involvement of teachers, administrators, and industry professionals to assure the quality of objectives, lesson plans, and activities.

Planet Earth

The *Planet Earth* curriculum is a required course for all tenth-grade Science Academy students. Students investigate major events in earth's past, present, and projected future. Current research is emphasized, and students synthesize information from astronomy, marine science, plate tectonics, geology, and biology to propose solutions to problems of global importance. Students use current technologies, such as satellite imaging and gas chromatography to collect data. They also participate in field studies of local geological and biodiversity issues, presenting their findings in a visual format (Science Academy course information).

The curriculum was written during the summer of 1991 by Science Academy science teachers with backgrounds in the relevant areas and was piloted at the Science Academy in the fall 1991 semester (Williams-Robertson, 1991). One distinctive aspect of this curriculum is that it does not use a textbook. Instead of a textbook, lessons include readings from a range of current sources. Course materials focus on the following:

- The intimate relationships between the physical and chemical aspects of the earth and earth's ability to provide a habitat for life,
- Concepts from physics, chemistry, biology, meteorology, astronomy, and mathematics to understand important issues related to planet earth,
- Use of current technologies to access, organize, synthesize, evaluate, and present information, and
- Application of scientific principles to personal interests, hobbies, and the consideration of potential careers.

For more detailed information on the curriculum of *Planet Earth* and its development, see Williams-Robertson (1991, 1992).

Student Survey

A survey developed by Science Academy staff, and modified by the Office of Research and Evaluation, was administered to *Planet Earth* students at the end of the spring 1993 semester (N = 36). The student survey revealed the following information (see Figure 8):

- The majority of students (53%) believed that the concepts they learned in their *Planet Earth* class are very important.
- Most students felt that the course was challenging (67%), intellectually stimulating (69%), and that their understanding of the planet's complexity is much clearer (77%).
- Over one third of the students indicated that the course material was new to them (36%). One student commented that although the topics were not new, the depth and detail of the topics were new.
- The majority of students (53%) asserted that their understanding of what scientists are currently working on has increased.
- Most (75%) students would recommend this course to other students.

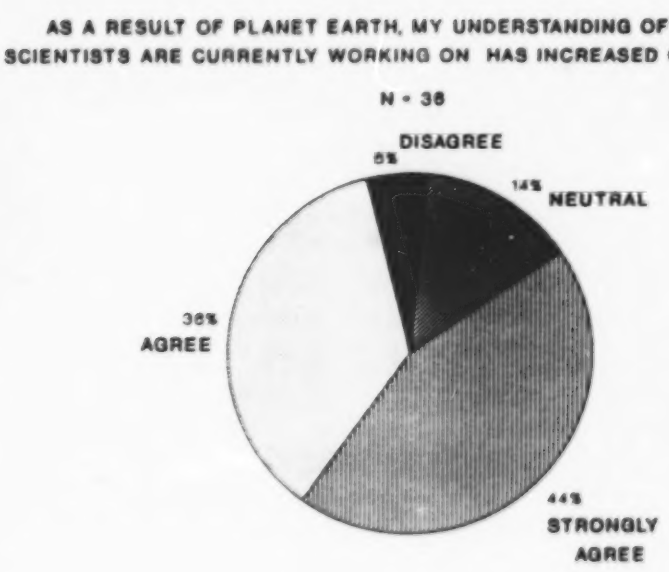
In addition, students were asked to list three concepts they enjoyed the most and three concepts they enjoyed the least. They were also asked to explain why they did or did not enjoy studying those concepts. The three favorite concepts listed most often were:

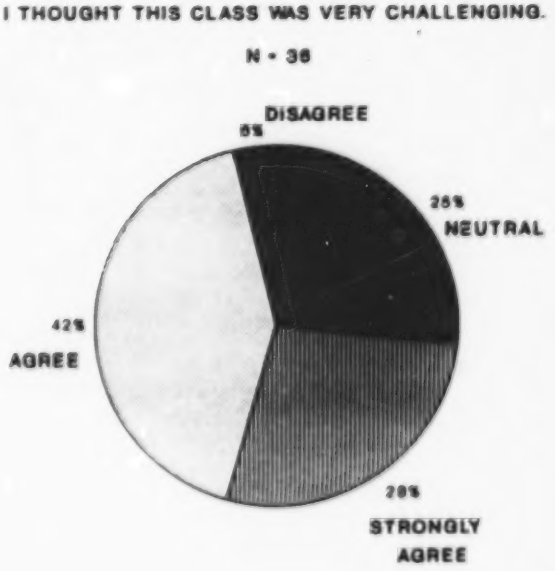
- Mass Extinction (69%) because students enjoyed the class debate on dinosaur extinction, learned how the environment affects life, and learned the geologic time scale;
- Biodiversity (50%) because students learned about other species, were able to understand how the human species interacts with the rest of planet life, and gained an understanding of the current situation on the planet; and
- Origin of Life (39%) because it was interesting and controversial.

The three concepts listed most often by students as "least liked" were:

- Earth's Structure (47%) because students did not understand what was going on, felt that the section required too much reading, had too few activities, and was boring;
- Plate Tectonics (39%) because the basic topic is covered in 8th grade and seemed too repetitive and boring; and
- Origin of Life (17%) because students had covered the topic before in another class, and the concept was too controversial and conflicted with religious teachings.

FIGURE 8
1993 *PLANET EARTH* STUDENT SURVEY RESULTS





Responding to the question, "What was the most important and/or interesting thing you learned from this class?" students responded:

- [I learned] how to collect data and present it.
- I learned a lot about performing field studies.
- That people and their actions can have a big effect on the biodiversity of the earth.
- The relationships between the different areas of science and how to apply them to each other.
- I learned to learn from doing and experiencing--versus from a textbook.

Finally, one enthusiastic student commented on the bottom of the survey that he/she felt this course should be designated as an honors class. "This class is hard! We deserve credit for it. Read the curriculum, sit in the class and you will see that this a good, innovative class that shows the true ability of American teachers and students."

Science and Technology

The *Science and Technology* curriculum is a required course for all ninth-grade Science Academy students. The course is divided into three major modules:

- Computers and computer applications,
- Engineering design, and
- Nuclear science.

Students use CAD (computer aided design software), are required to execute three-dimensional graphics, and study telecommunications (including computer networking). They also design, build, and test an engineering project applying physics and mathematics concepts learned in class (see "Classroom Observations").

The committee that was organized to develop the course included: University of Texas professors in the areas of physics, engineering, and science education; a consultant from the Governor's energy office; Science Academy teachers with collective expertise in computers, the physical sciences, mathematics, and biology; and the Science Academy Curriculum Coordinator (see "Linkages" for detailed information). Additionally, advice was sought from curriculum experts from the District's central office.

Objectives for the end of the course are that students should be able to:

- Communicate an understanding of the interactions between science, technology, and society and the economics related to this interaction;
- Apply concepts of physics and mathematics to design, construct, test, and evaluate a mechanical device that performs a specific assigned task;

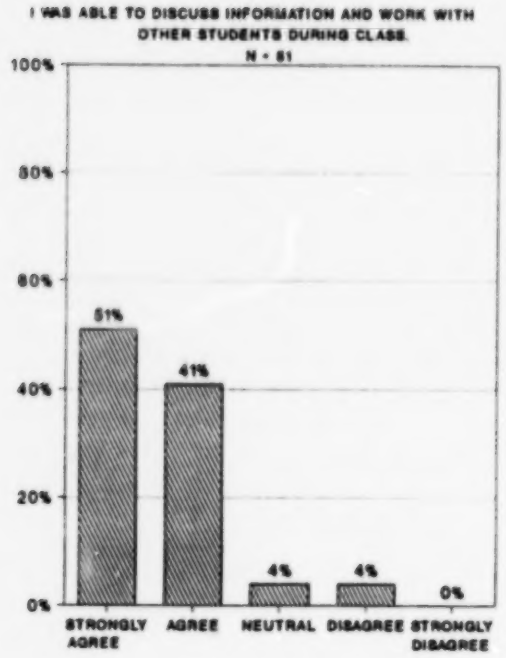
- Propose solutions to a complex societal problem that relates to community needs, and that requires a solid understanding of fundamental concepts of the physical sciences and technology;
- Demonstrate the ability to utilize telecommunications to access, manipulate, and send information;
- Collect physical measurement data, and derive conclusions based on those data;
- Communicate technical information effectively via written, graphic, and verbal means;
- Demonstrate effective techniques to manage time and materials;
- Define what comprises quality work, and evaluate their own and others' work based on set criteria; and
- Demonstrate a wide variety of competencies on the personal computer equipped with a modem, including skills in the disk operating system (DOS) and the use of programs for work processing, spreadsheets, statistics, drawings, and other graphics.

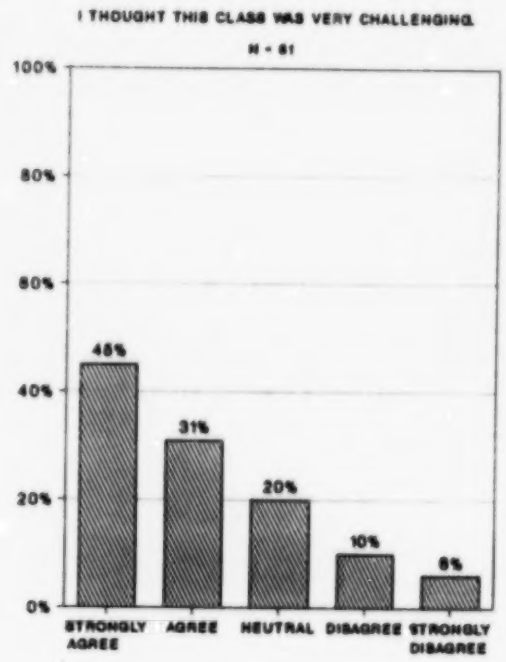
Student Survey

A survey developed by Science Academy staff, and modified by the Office of Research and Evaluation, was administered to *Science and Technology* students at the end of the spring 1993 semester (N = 51). The student survey revealed the following information (see Figure 9).

- Two thirds (65%) of the students strongly agreed or agreed that the information they learned in their *Science and Technology* class is very important.
- Most of the students strongly agreed or agreed that the class was very challenging (76%) and intellectually stimulating (69%).
- Almost half of the students strongly agreed or agreed that as a result of taking this class, they plan to do more to further their understanding of physics concepts and applications (43%); 25% were neutral, and 35% did not plan to do more.
- The activities that students most enjoyed were building the mousetrap car and the computer activities. The most important and/or interesting activities were learning computer skills, the engineering process, and learning how to use power tools to build things.
- The majority of students (73%) strongly agreed or agreed that they would recommend this course to other students.

FIGURE 9
1993 *SCIENCE AND TECHNOLOGY* STUDENT SURVEY RESULTS





Teacher Survey

The teachers involved with teaching the *Science and Technology* course meet each day to discuss the course plans and evaluations. The main reason these teachers meet daily is to keep the instruction of the classes as standardized as possible. Three teachers who taught the course during the 1992-93 school year were given a brief questionnaire with six open-ended questions. The questions addressed teacher perceptions of the collaborative effort in planning and student evaluation, as well as their perception of the course itself.

Responding to the question, "How valuable was collaboration to the planning of this curriculum?" teacher responses included:

- Extremely valuable. Each of us have certain strengths and weaknesses and we complemented each other well. We were able to brainstorm ideas and objectives.

- Invaluable. The teaming this semester was the best I've experienced in my professional career (education and business). Project conceptualization and execution demands coordinated team work. The collaborative efforts reduce stress, due to time management and idea creation.

In response to the question, "How does this curriculum compare with the current science curriculum?" teacher responses included:

- Better in many ways. Concepts are taught and acquired in context of an application of the concepts. No extraneous facts are taught unless it directly relates to project success. The science concepts will be recalled in context.

- Our program is more self-paced, it adapts well to different levels of computer literacy as well as mechanical ability. The approach is more hands-on and more dynamic. Most of our work was done in the classroom, with little homework or worksheets.

Teachers responded to "How valuable will this curriculum be to your students and why?" with:

- Very valuable. It teaches application of learning to real-world problems, management of a major project/problem with subdivision into small steps and integration of component solutions, many computer skills and time management.

- [Presently] our best students never produce any outcomes based on the basic skills we teach; therefore, the validity of the skills has never been verified and possibly never learned. This course tests [learning] concepts through application.

- This course acts as a foundation to problem-solving, computer literacy, technical field requirements, even mechanical skills. The skills learned in the computer lab will apply to any science course, and I believe the students learned to break a problem down to components to solve it.

TEA Approval

The *Science and Technology* course was submitted for approval to the Texas Education Agency for honors credit and statewide use. Approval was granted in 1993 and a consultant was hired in December 1993 to transfer the objectives, lesson plans, etc., into a format that can be used for distribution. This process began in January 1994. The project should be completed by the end of 1994.

CLASSROOM OBSERVATIONS

Students in *Physics and Technology* classes were observed to determine if this NSF-funded curriculum appears to motivate students to learn. Students were observed working on their projects, often in groups of two or three, for long periods of time. There was also evidence that students worked after school or at home. Observations that the curriculum design promoted intrinsic motivation were supported by teacher and student interviews.

One of the two major goals of the NSF grant to the Science Academy is "to increase student learning and performance in science using holistic, interdisciplinary approaches with opportunities to apply concepts in real-world settings." A subgoal is to create a "thinking curriculum." These goals have been at the heart of NSF-funded curriculum development.

The NSF-funded curriculum *Physics and Technology* was selected by the Science Academy director for observations during the fall 1992 semester. The purpose was to determine if the students of this NSF-funded curriculum appear to be motivated actively in the learning of science, particularly in the area of physics. The *Physics and Technology* course was chosen because it centers on "project-based" learning, a design that is purported to engage students in investigation of authentic problems and positively affect student motivation (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991). During the fall 1992 semester, this curriculum was taught by three teachers. However, because of time constraints, only two teachers and their classrooms were selected for observation.

Data Collection and Analysis

Each class runs through two class periods and is, therefore, two hours long. The first class that was observed met from 7:50 am until 9:50 am. The second observed class met from 11:15 am until 1:15 pm. Both classes were observed every day, in mid-November 1992, during the final "construction" phase, and evaluation phase, of student projects. During this time, field notes were taken of observations.

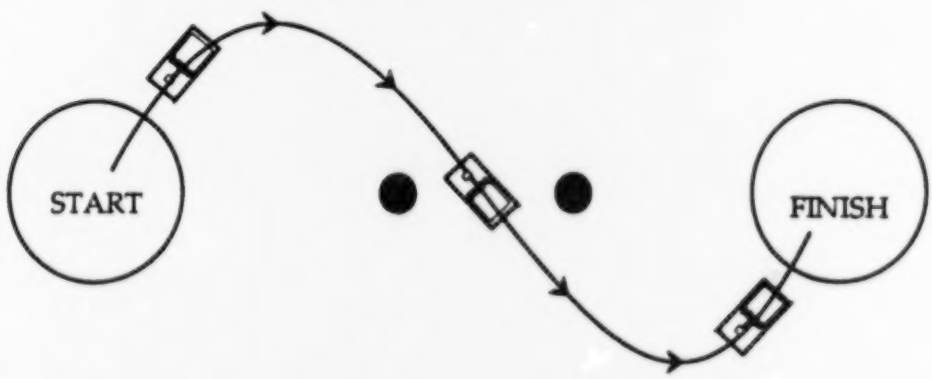
In addition to the classroom observations, classroom teacher interviews were conducted during teacher office hours and student interviews were conducted during class breaks. All interviews were tape-recorded and transcribed verbatim.

Observation field notes and interview transcriptions were analyzed for categorical and thematic content. The intention of the analysis was to determine if the students of this NSF-funded curriculum appear to be motivated actively in the learning of science, particularly in the area of physics. Two areas were of interest. The first concerned apparent student motivation. Was there evidence that the students were motivated to learn the material? The second area of interest concerned the curriculum. In its design, was the program consistent with motivation research with regard to enhancing students' motivation to learn material?

Course Description

The unit of the physical science course observed covered 12 weeks. During this period students learned basic physical science concepts, mechanical drawing skills, use of woodshop machines, and various computer skills. The acquisition of skills culminated in the conceptualization, design, construction, and testing of a "mousetrap car." The mousetrap car was powered solely by the energy produced by a mousetrap. In addition to designing a mousetrap car, powered by its own energy, additional requirements were specified. The car was to run a "track." This track required that the car start in one circle, do an "S" curve through two pylons and stop within another circle on the other side of the pylons (see Figure 10).

FIGURE 10
MOUSETRAP CAR TRACK



Observed Indications of Student Motivation

There is no standard measure for student motivation. Student motivation is often inferred from the amount of time students are willing to spend on a task, their ability to stick with the task when it becomes difficult, the intensity of their involvement, and whether they appear to have the desire to master the task (Deci & Ryan, 1985). The following observations were made of the two classes:

- Most students were working intently, either by themselves or in groups of two, sometimes three.
- Most students would work for long periods of time (up to two hours), often not taking a break. In fact, more students would not take a break than would. Many students worked during lunch, during breaks, and during a football pep rally (held for the city playoffs!).
- Students worked after school or at home. One student showed up each day with different wheels he had made. Examples of comments included, "I don't understand, it worked perfectly at home!" or "When I tried it at home it worked fine."

In addition, one teacher offered his observation of student motivation when it actually came time to produce the cars:

> The difference I saw when we went from the classroom. . . . when we transferred downstairs, all of a sudden people were anxious to get down there. They were waiting at the door. As soon as the door opened they were in there and they were working. The bell would ring to take a break and they wouldn't leave until I was yelling at them to put their stuff away and get packed up so they could get out of there. Lots of people came running up to me with parts and design ideas and saying, "Do you think this would work?"

Curriculum Design and Intrinsic Motivation

Intrinsic motivation is believed to be an inborn, internally generated psychological drive. It is a natural tendency that engages a person's curiosity and interest. Such motivation occurs when interesting activities are optimally challenging, and it is sustained without external rewards or control (Deci & Ryan, 1990). Within the educational setting, intrinsic motivation is illustrated when a student's natural curiosity and interest energize the student's learning. Two major components of intrinsic motivation are the need for *self-determination* and the need to feel *competence*. The need for self-determination refers to people's need to feel autonomous and the need to feel like they are the origin of their actions. The need for competence encompasses people's need to feel that they can control or have an effect on outcomes, and that the effect is predictable and reliable. When these psychological needs are nurtured within a curriculum, classroom, and/or by a teacher, intrinsic motivation is believed to be promoted or enhanced. However, when one or more of these psychological needs is frustrated, as by a restrictive, or discouraging, teacher/environment, intrinsic motivation can be impaired (Deci & Ryan, 1985). Learning environments can enhance or inhibit students' psychological needs for self-determination and/or competence and ultimately affect their motivation to learn.

Self-determination

Within the dimension of self-determination, having the freedom to make choices has been shown to enhance intrinsic motivation (Deci & Ryan, 1985). Students need to feel they have choices in order to feel some amount of control and determination in their learning. In fact, events such as demands, rewards, and deadlines have been shown to promote feelings of outside control, and consequently, they undermine intrinsic motivation (Deci & Ryan, 1985).

Both teachers observed expressed the idea that the Physics and Technology course was successful because it promoted student autonomy. One teacher believed that the reason students were driven to work hard on their project was

> The fact that much of their work was self-directed . . . and the fact that they were given the latitude to try a range of activities, and to make their own mistakes.

The other teacher elaborated on this idea and explained that the project permitted--even directed--students to pursue the development/creation/construction of their own concepts. He considers this aspect to be the cornerstone of their motivation and learning. This teacher commented:

> This stuff gets more at the core of intrinsic motivation because the course requires the student to take one of their own ideas and bring it out into fruition on the table.

This same teacher was able to articulate the differences in student behaviors he has observed over time between a rigorously structured, traditional class and the present nontraditional approach. When asked what evidence he saw that the students were really motivated, he replied:

> Their path to the conclusion on these open engineering projects is their own--within the limits that we've established. They recognize the limits that we establish as outside limits that they can't cross, and we tell them they can't cross. But within those limits we establish, there are a hundred thousand ways of meeting the deal. So they realize their path is their own.
>
> So to answer your question. . . . The way I know they're motivated more in this project than others is because, in those other projects where I dictated every step, they wouldn't stay at it. I mean we would lose kids a lot earlier in the project. In other words, they would just quit, or they would figure that they can't do it and there was nothing else to tell them they could. They'd already made the decision... OK? So, we lost them earlier. They wouldn't stay after school and work, wouldn't stay at lunch and work, wouldn't come to you and quiz you in a collaborative way.

Furthermore, it should be noted that the students had a freedom of movement rarely experienced in a traditional class setting, especially when the cars were being built and tested. In the woodworking shop, students roamed about spontaneously pursuing their interests and marshalling resources, as necessary. If they needed supplies or help with machinery, they would consult the teacher. They were also free to ask their classmates for help. Students were often observed working together. Usually they were observed working in dyads. But on one occasion, as many as six students were seen working on a problem.

Competence

The second major component of intrinsically motivating environments is the enhancement of peoples' feelings of competence. Deci & Ryan (1985) noted that, "The more competent a person perceives him- or herself to be at some activity, the more intrinsically motivated he or she will be at that activity" (pg. 58). Students need to feel capable of participating in activities in ways that they know will affect the outcome. However, intrinsic motivation will not be engaged unless the activity is both optimally challenging and interesting. Because "boring" problems hold no challenge or novelty, students are not intrinsically motivated to continue working with them for a sustained period of time.

Both teachers perceived that the curriculum design and engineering project contained necessary ingredients for intrinsic motivation. The first teacher offered:

> A lot of the motivation came from it [the project] being so unusual. No other class is taught like this. The newness is certainly a novelty, and a consideration.

One student offered in his interview that he enjoyed the engineering project because "it was really fun and interesting. I had never designed anything before and it was really fun."

Concerning the need for activities to be optimally challenging, the second teacher expressed his belief that:

> At every step, challenge and complexity is what's motivating. I think that's where some of the intrinsic motivation comes from. . . the complexity of the problem. We make our projects as complex as we possibly can within the time frames.

Students also echoed this theme when asked what they enjoyed about the engineering project. One student expressed, "It's challenging every day, and I like that," while another student offered, "It is challenging but fun, like all classes should be."

In order to experience the feeling of competency, there is also a need to develop effective learning and study strategies. It is believed that with the foundation of past success and the development of effective learning and study strategies, learning (and the desire to learn) can take place (Deci & Ryan, 1990). The first teacher seemed to be aware of this when he reported:

> We wanted to give them a problem that they could not see immediately to the end. And a problem that they might not have any idea how to solve. A problem large enough that they had to break it down into components and then solve each of those component problems.

The second teacher also acknowledged the importance of responding to the need for complexity, while observing the need for effective strategy, to promote student learning. He expressed that

> The more complex it is, the more they feel like they can't do it. And then you teach them the steps of engineering in which they <u>can</u> do it, a very simple way of organizing their mind and efforts into the five categories that we established for these goals--conceptualization, just a general getting a handle on what's going to happen; then the design part which takes that broad conceptual idea and then fine-tunes it into a drawing; then into a scaled dimension; and then a 3-dimensional drawing. Then, once they make it through the drawing, it is <u>obvious</u> that they can do this. And it blows them away.

This combination of complexity and strategy was not lost on one student as he explained,

> I think the mousetrap car will be valuable to me because I enjoy challenges like this and now I know how to go about to solve those problems.

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Austin Independent School District

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